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SPONTANEOUS COMBUSTION OF COAL - DISCUSSION SUMMARY

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SPONTANEOUS COMBUSTION OF COAL: DISCUSSION SUMMARY

by

N.A. Mansour*

ABSTRACT

This report summarizes the opening remarks and panel discussion of a one day Spontaneous Combustion seminar held on November 13, 1987 at Calgary, Alberta. This seminar was sponsored by the Alberta Office of Coal Research and Technology (AOCRT).

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COMBUSTION SPONTANÉE DU CHARBON : SOMMAIRE DE LA DISCUSSION

par

N.A. Mansour*

RÉSUMÉ

Le présent rapport résume les remarques d'ouverture et les discussions en atelier tenues lors du colloque sur la Combustion spontanée qui a eu lieu le 13 novembre 1987 à Calgary en Alberta. Ce colloque a été parrainé par l'Alberta Office of Coal Research and Technology (AOCRT).

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1. INTRODUCTION

The Spontaneous Combustion of Coal seminar included seven presentations:

1. Session Chairman's Keynote Speech
N. Berkovitz
Professor, Mineral, Metallurgical and Petroleum
Engineering Department, University of Alberta.
2. "Overview of Spontaneous Combustion of Australian
Coals".
C. Roberts
Manager of Coal Processing ACIRL, Australia.
3. "Spontaneous Combustion Potential of Coal".
C.P. Lazzara
Supervisory Research Scientist
U.S. Bureau of Mines
Pittsburgh Research Center
4. "Research in France Pertaining to the problem of
Spontaneous Combustion".
D. Carson
CERCHER
5. "Susceptibility of Canadian Coals to Spontaneous
Combustion".
R. Chakravorty and R.J. Mikula
Coal Research Laboratories, CANMET.
6. "Chemistry of Spontaneous Combustion".
F. Bachelor
Chemistry Department, University of Calgary.
7. "Overview of Spontaneous Combustion Modelling".
M. Otwinowski

Chemistry Department, University of Calgary.

The following outlines the main aspects of the chairman's keynote speech together with the questions and answers from the panel discussion.

2. OPENING REMARKS BY SESSION CHAIRMAN

The following summarizes the opening remarks by Dr. N. Berkowitz, Session Chairman.

2.1 AUTOGENOUS HEATING OF COAL

What we now know (or think we know) about the chemistry of atmospheric oxidation of coal makes it semantically more correct to refer to AUTOGENOUS HEATING rather than to SPONTANEOUS COMBUSTION of coal. Spontaneous combustion - i.e., generation of CO and CO₂ - results from an uncontrolled process that begins by altering the molecular structure and surface chemistry of the coal

- (1) through chemisorption of oxygen;
- (2) through generation and decomposition of peroxides and hydroperoxides; and
- (3) as a result of (2), through insertion of oxygen-bearing functional groups such as -COOH, -OH, =CO and -O- into coal 'molecules'.

All three of these oxidation effects can be verified by recourse to experiments.

We also know that in a statistical sense - but only in that sense because coals with very similar elemental compositions can behave very differently - oxidizability of coal decreases with increasing rank, partly because metamorphic development promotes aromatization, and partly because this process is accompanied by increasing compaction of the coal substance and by a consequent loss of porosity.

But despite qualitative understanding of coal oxidation, and an ability to quantify its principal features, our perceptions of autogenous heating are 'spotty'.

First, broadly reflecting coal oxidizability, autogenous heating is a rank-function, so that a liability to heat up diminishes from lignites to high volatile bituminous coals, and more mature coals are, for all practical purposes, 'safe'. Expressed in another way: coals with relatively low porosities - equivalent to capacity (=bed) moisture contents below 10-12% - will usually pose little hazard.

Secondly, oxidation of FeS_x can only be a contributory factor: low rank coals that are virtually devoid of FeS_x are no less prone to autogenous heating than their high-pyrite counterparts.

And thirdly, moisture plays an important dual role, (1) because wetting of partially dried coal releases heat, and (2) because it promotes formation of peroxide complexes in the coal. The role of wetting in promoting autogenous heating of coal was experimentally demonstrated some 45 years ago in the laboratory; was repeatedly confirmed in the 1960's, and is reflected in admonitions to coal engineers to ensure that open coal stockpiles are prevented from drying out. And the bearing of water on peroxide/hydroperoxide formation was emphasized as early as 1945.

But while there is agreement that the ultimate heat source for autogenous heating is oxidation of carbon, we are still not able to unequivocally define how, or under what conditions, that oxidation can lead to heat accumulation and, ultimately, to ignition of the coal.

It has been argued that heats of wetting are sufficient to raise oxidation rates six to eight times, and that such elevated rates would suffice to start an accelerating oxidation process - especially if, as is widely supposed, such a process involves meandering hot spots in a storage pile. One might then suppose that there is a statistical probability of a hot spot 'dying' or causing ignition of coal within its 'sphere of influence'.

But there are, of course, other ways of looking at it - as is in fact done in several mathematical models that have been put forward to 'describe' autogenous heating. And there remains, as well, some imponderables about which we can say little, if anything. For example, can mineral species in coal catalyze the oxidation? Do the initial stages of oxidation, i.e., generation of peroxides and/or oxygen-bearing functional groups, enhance oxidizability (and, therefore, rates of carbon oxidation)? And can air-flow through a storage pile evaporate and redeposit moisture elsewhere, and in that manner contribute to the 'meandering' of hot spots?

At present, the best we can do in practice is to think solely of moisture and oxygen as the parameters of autogeneous heating - and to construct storage piles so as to minimize (a) drying out of the coal, and (b) access of air to do it. But what must we do if we wish to transport potentially hazardous coals safely? Or if we want to store it without incurring the inconvenience (and cost) of current stockpile construction procedures? And how can we reliably assess the liability of a given coal to autogeneously heat?

3. QUESTIONS AND ANSWERS

Question 1:

1. From: Brian Wong,
Gulf Canada

Most reaction tests use moist air and record the temperature rise. In fact, it was shown by various researchers that moist air is required for the temperature rise. You mentioned that in Australia dried oxygen was used in the reaction tests. Could you comment on why this will give temperature rise which was not observed by others?

Answer: Dr. Clive Roberts, Manager
Coal Processing ACIRL, Australia

The ACIRL "adiabatic" calorimeter uses dry oxygen gas and the coal is of a particular size fraction and is dried in the reaction vessel prior to reaction. Oxidation occurs with the attendant temperature rise. Moisture is not required to "activate" the reaction. The self heating rate with moist oxygen has been measured in "non-standard" tests, and the rate has been found to be higher than that from the "standard" dry conditions.

Question 2:

From: Dr. N.H. Wade,
Monenco Consultants, Calgary

Is the only coal which is safe against spontaneous combustion that which is below the water table ?

Answer: Prof. N. Berkowitz, Professor
Department of Mining Metallurgical and Petroleum
Engineering, University of Alberta

There is a general consensus that moisture plays a role in triggering spontaneous combustion in coal. In practice, it was found that if capacity (=bed) moisture is less than 10 - 12%, coal is relatively 'safe'. Clearly the amount of heat generated depends on the total surface area i.e. it is a function of porosity of coal. As a rule of thumb if the coal is dried to 2/3 of its moisture content then we are expecting spontaneous combustion problems.

Question 3:

From: Mr. T. Frankiewicz
Unocal
Mr. John Hinds
Obed Coal Co.

We do not understand Dr. Bachelor's results relating the amount of heat released when water is readsorbed onto coal to the fraction of equilibrium moisture which was

removed. If one coal readsorbs twice as much water as another, should not about twice as much heat be released ?

Answer: Dr. F. Bachelor
Chemistry Department
University of Calgary

Based on experiments conducted in our laboratory heat rise appear to be a function of percent equilibrium moisture.

Answer: Prof. Berkowitz
Professor, Mineral, Metallurgical and Petroleum
Engineering Department, University of Alberta.

It is not the amount of water adsorbed, but the amount of water as a fraction of the equilibrium moisture (capacity moisture) content.

Question 4:

From: Garry Pangracs
Obed Mountain Coal

From a mine operators point of view, we have an operational drying process designed to dry 4% below equilibrium moisture of 12%. We have experienced in its operation all symptoms related to spon comb, dusting etc.. Where do we go from here ? We have heard what has been done; we should decide what needs to be done.

Answer: Prof. N. Berkowitz
Professor, Mineral, Metallurgical and Petroleum
Engineering Department, University of Alberta.

I do not have a straight answer for this problem. Did you dry the coal to 8% moisture for economic reasons Your coal with 12% equilibrium moisture is potentially hazardous. The liability to heating decreases if coal is previously oxidized, so I suggest that the coal may be put in a fluidized bed dryer for pre-oxidation which may help to control spontaneous combustion.

Dr. R. Chakravorty
Surface Mining Laboratory/CANMET, Devon

Your coals have a problem to start with and drying your coal will further aggravate the situation. Some pre-treatment is required to prevent spontaneous combustion. By proper compaction the hazard to spontaneous combustion may be decreased in a coal pile.

Mr. S. Butcher
CMRC, Devon

The number one lesson we can learn from the Obed case is that we have to develop a large scale test to determine spontaneous combustion liability for low rank coals.

Mr. R.D. McDonald
AOCRT, Edmonton.

We have a mine with coal that has a problem. Now the challenge is how can we stabilize this coal? Drying below a certain moisture level is hazardous. If drying is not the answer can we suggest some other procedures to make the product safe and marketable.

Mr. Garry Pangracs
Obed Mountain Coal

If drying will cause problems, AMAX in USA are using a treating agent to stabilize their coal. Can we in Alberta use similar technique to overcome the problems for these types of coal.

Dr. R. Chakravorty
Surface Mining Laboratory/CANMET, Devon

We may be able to reduce susceptibility to spontaneous combustion by treating the coal with carbon dioxide.

Prof. N. Berkowitz
Professor, Mineral, Metallurgical and Petroleum
Engineering Department, University of Alberta.

During drying, lignites and subbituminous coals show some irreversible shrinkages. Further, technology is available for safe drying of coal or lignite: in this, the pores are blocked so that reduction of moisture becomes irreversible.

Question 5:

From: Mr. T. Frankiewicz
Unocal

What do you think about the chemistry that makes CaCO_3 an effective self heating inhibitor ?

Answer: Prof. Berkowitz

Professor, Mineral, Metallurgical and Petroleum Engineering Department, University of Alberta.

If CaCO_3 gets near a hot spot it loses CO_2 which can enclose the hot spot and effectively kill it.

Question 6:

From: Mr. Brian Wong
Gulf Canada

You mentioned the use of different inhibitors to reduce spontaneous combustion risk. What is the basis for choosing these inhibitors ? What mechanisms (reactions) are they inhibiting ?

Answer: Dr. C.P. Lazzara

Supervisory Research Scientist
U.S. Bureau of Mines
Pittsburgh Research Center

All the additives that we looked at, except for CaCO_3 , were soluble in water. They were first dissolved in water and then mixed with coal. Rock dust (CaCO_3) is commonly used in mines to prevent coal dust explosions. Several of the other additives were selected on the basis of the results of other researchers.

Most of these inhibitors are dissolved in water, mixed with coal to make slurry, and then dried with nitrogen. The mechanism here is of a thermal or mechanical nature, blocking the pores for coal deactivation. We looked at NaCl which is used in European mines.

Dr. R. Chakravorty
Surface Mining Laboratory/CANMET, Devon

Many coal producers in India have successfully used sodium silicate to prevent spontaneous combustion problems in coal pillars.

Dr. Clive Roberts
Coal Processing ACIRL, Australia

Inhibitors work for high rank coals but do not work for low rank coals. Dust suppressants are commonly used to prevent spontaneous combustion problems with limited success.

Dr. R. Chakravorty
Surface Mining Laboratory/CANMET, Devon

The mechanism by which these inhibitors work is not clearly established. It appears that the phenomenon is partly physical and partly chemical.

Question 7:

From: Mr. T. Frankiewicz
UNOCAL

++ +++
Please comment on Fe⁺⁺/Fe⁺⁺⁺ redox couple as a potential contributor to spontaneous combustion. Iron can come from minerals other than pyrites.

Answer: Dr. F. Bachelor,
Chemistry department
University of Calgary

Certainly some heating might be observed as suggested but it is not a major contributor.

Question 8:

Mr. T. Frankiewicz
UNOCAL

In moisture adsorption onto coal,
Total heat released = Heat of condensation of water +
heat of immersion.
Heat of immersion can be 150 cal/gm water adsorbed.
Therefore coal heating can be more serious than you
estimated in your talk.

Answer: Dr. D. Carson
CERCHER, France

It is a very complicated process. This is due to the
interaction of water with the coal sample and we do not
measure the heat of wetting. What we exactly measure in
our tests is the rise in temperature due to moisture
pickup.

Question 9:

Mr. T. Frankiewicz
UNOCAL

At what point did you add the self-heating inhibitor
(before or after drying) ? How much was added ?

Answer: Dr. C. Lazzara
Supervisory Research Scientist
U.S. Bureau of Mines
Pittsburgh Research Center

The salt additives were dissolved in a minimum amount of
water and the solution was mixed with the coal. The
coal additive mixture was then dried under nitrogen.
15% by weight of the inhibitor was added to the coal.
The CaCO_3 was applied as a water slurry and dried.

Question 10:

Mr. T. Frankiewicz
UNOCAL

Ships are fond of using inert gas when transporting combustible material. Has any attempt been made to determine if the use of inert gas system on a ship has contributed to coal fires ?

Answer: Dr. Clive Roberts
Coal processing ACIRL, Australia

I am not aware of any coal ships now using inert gas systems to prevent heating. The successful use of moist flue gas would depend upon several factors, such as its oxygen content and the moisture content of the coal. The use of dry CO_2 or N_2 would be preferable for some coals.

Question 11:

Dr. N.A. Mansour
Surface Mining Laboratory/CANMET, Devon

You have considered your model to be one-dimensional as a function of X. In practice the spontaneous combustion problem in stack piles is three dimensional, can you comment on that ?

Answer: Dr. M. Otwinowski
Chemistry department
University of Calgary

The one dimensional model gave us a feel for the three dimensional case. We have enough data to go ahead and consider the three dimensional case. Stability analysis can give us guidance on the range of temperature which should not be exceeded in stock piles.

Prof. N. Berkowitz
Professor, Mineral, Metallurgical and Petroleum
Engineering Department, University of Alberta.

The heating phenomenon in stock piles should be considered in a statistical sense, since we deal with meandering hot spots in the pile.